

## Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.



69 B

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 65.

B. T. GALLOWAY, *Chief of Bureau.*

## RECLAMATION

OF

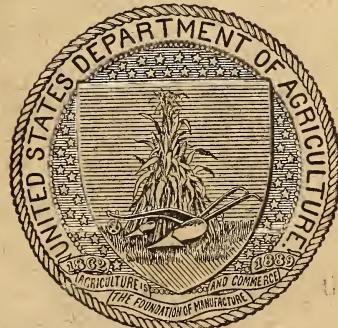
# CAPE COD SAND DUNES.

BY

J. M. WESTGATE,  
ASSISTANT IN SAND-BINDING WORK.

GRASS AND FORAGE PLANT INVESTIGATIONS.

ISSUED JUNE 30, 1904.



LIBRARY

RECEIVED  
JULY 7 - 1904

U. S. Department of Agriculture

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1904.

## BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

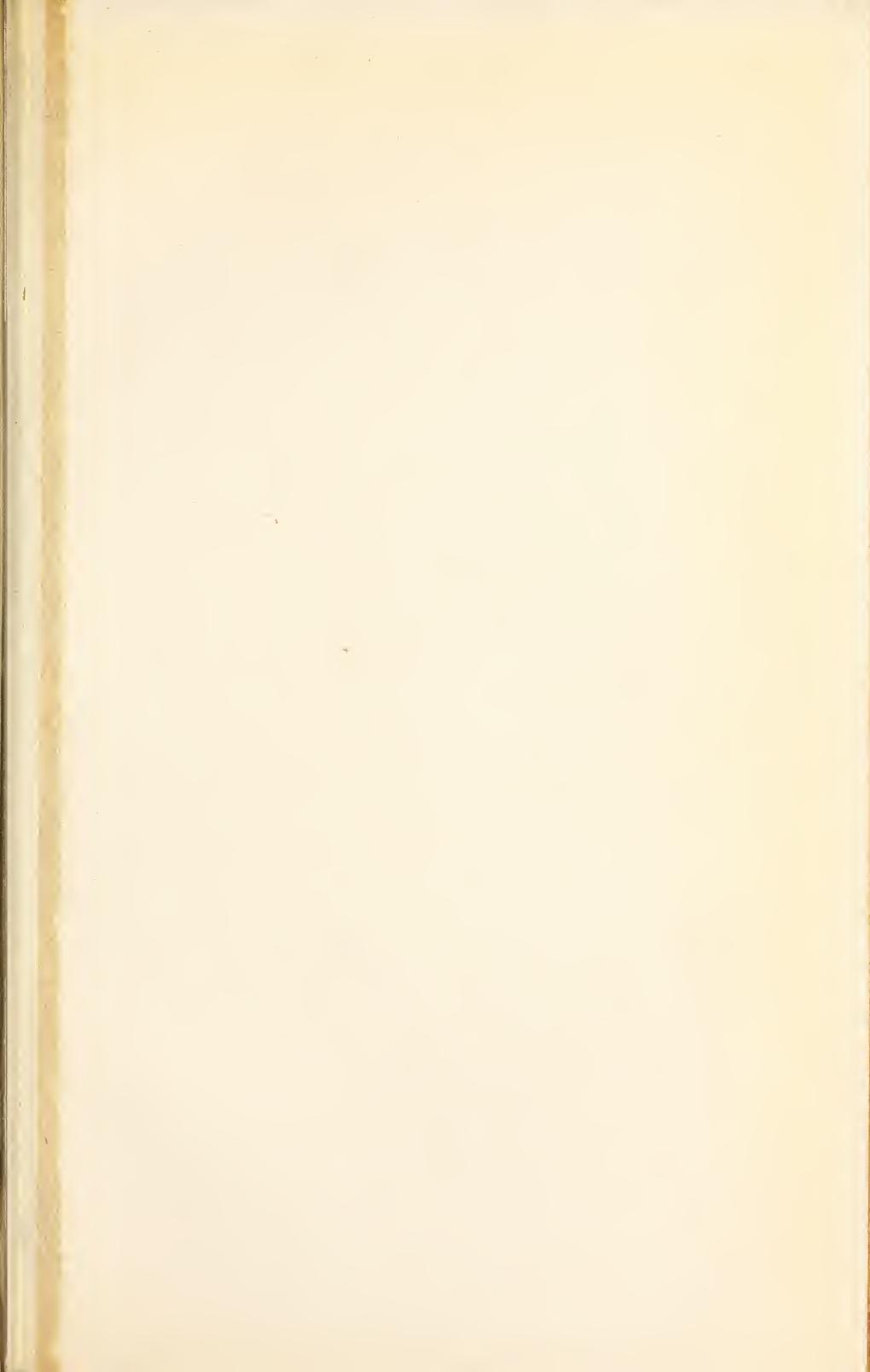
The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

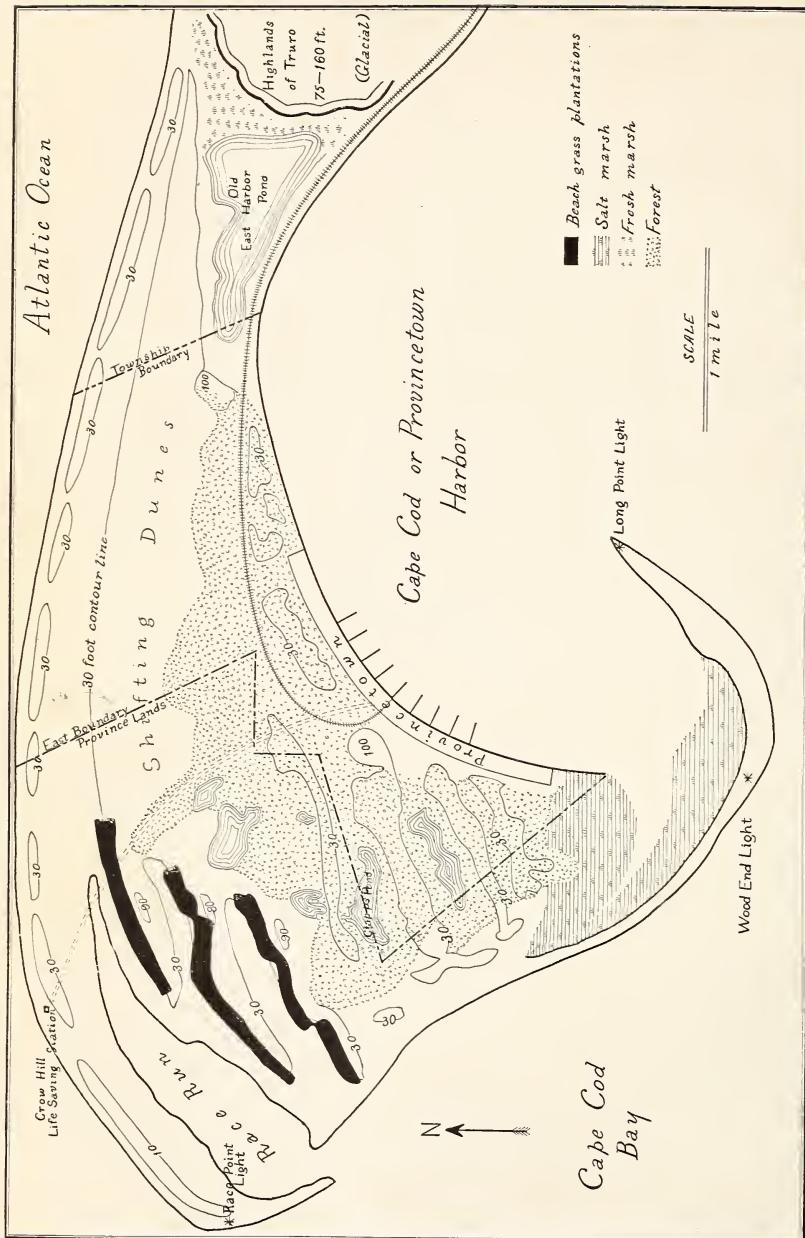
Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to the Superintendent of Documents, Government Printing Office, Washington, D. C.

- No. 1. The Relation of Lime and Magnesia to Plant Growth. 1901. Price, 10 cents.
2. Spermatogenesis and Fecundation of *Zamia*. 1901. Price, 20 cents.
3. Macaroni Wheats. 1901. Price, 20 cents.
4. Range Improvement in Arizona. 1902. Price, 10 cents.
5. Seeds and Plants Imported. Inventory No. 9. 1902. Price, 10 cents.
6. A List of American Varieties of Peppers. 1902. Price, 10 cents.
7. The Algerian Durum Wheats. 1902. Price, 15 cents.
8. A Collection of Fungi Prepared for Distribution. 1902. Price, 10 cents.
9. The North American Species of *Spartina*. 1902. Price, 10 cents.
10. Records of Seed Distribution and Cooperative Experiments with Grasses and Forage Plants. 1902. Price, 10 cents.
11. Johnson Grass. 1902. Price, 10 cents.
12. Stock Ranges of Northwestern California: Notes on the Grasses and Forage Plants and Range Conditions. 1902. Price, 15 cents.
13. Experiments in Range Improvement in Central Texas. 1902. Price, 10 cents.
14. The Decay of Timber and Methods of Preventing It. 1902. Price, 55 cents.
15. Forage Conditions on the Northern Border of the Great Basin. 1902. Price, 15 cents.
16. A Preliminary Study of the Germination of the Spores of *Agaricus Campestris* and other Basidiomycetous Fungi. 1902. Price, 10 cents.
17. Some Diseases of the Cowpea. 1902. Price, 10 cents.
18. Observations on the Mosaic Disease of Tobacco. 1902. Price, 15 cents.
19. Kentucky Bluegrass Seed: Harvesting, Curing, and Cleaning. 1902. Price, 10 cents.
20. Manufacture of Semolina and Macaroni. 1902. Price, 15 cents.
21. List of American Varieties of Vegetables. 1903. Price, 35 cents.
22. Injurious Effects of Premature Pollination. 1902. Price, 10 cents.
23. Berseem; The Great Forage and Soiling Crop of the Nile Valley. 1902. Price, 15 cents.
24. Unfermented Grape Must. 1902. Price, 10 cents.

[Continued on page 3 of cover.]





MAP OF THE SAND AREAS INCLOSING CAPE COD HARBOR.

U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 65.

B. T. GALLOWAY, *Chief of Bureau.*

---

# RECLAMATION

OF

# CAPE COD SAND DUNES.

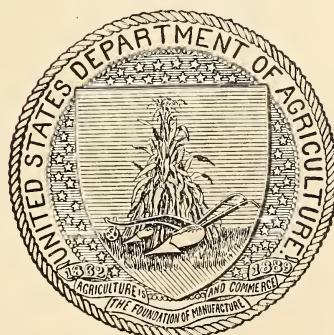
BY  
J. M. WESTGATE,  
ASSISTANT IN SAND-BINDING WORK.

---

GRASS AND FORAGE PLANT INVESTIGATIONS.

---

ISSUED JUNE 30, 1904.



WASHINGTON:  
GOVERNMENT PRINTING OFFICE.  
1904.

## BUREAU OF PLANT INDUSTRY.

BEVERLY T. GALLOWAY, *Chief.*  
J. E. ROCKWELL, *Editor.*

### GRASS AND FORAGE PLANT INVESTIGATIONS.

#### SCIENTIFIC STAFF.

W. J. SPILLMAN, *Agrostologist.*

A. S. HITCHCOCK, *Assistant Agrostologist, in Charge of Cooperative Experiments.*  
C. V. PIPER, *Systematic Agrostologist, in Charge of Herbarium.*  
C. R. BALL, *Assistant Agrostologist, in Charge of Work on Arlington Farm.*  
DAVID GRIFFITHS, *Assistant Agrostologist, in Charge of Range Investigations.*  
S. M. TRACY, *Special Agent, in Charge of Gulf Coast Investigations.*  
P. L. RICKER, *Assistant in Herbarium.*  
J. M. WESTGATE, *Assistant in Sand-Binding Work.*  
BYRON HUNTER, *Assistant in Agrostology.*  
MATT. A. CROSBY, *Assistant in Farm Management.*  
R. A. OAKLEY, *Assistant in Agrostology.*  
C. W. WARBURTON, *Assistant in Farm Management.*  
AGNES CHASE, *Agrostological Artist.*

## LETTER OF TRANSMITTAL.

---

U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF PLANT INDUSTRY,  
OFFICE OF THE CHIEF,  
*Washington, D. C., May 10, 1904.*

SIR: I have the honor to transmit herewith a paper on "Reclamation of Cape Cod Sand Dunes," and respectfully recommend that it be published as Bulletin No. 65 of the series of this Bureau.

This paper was prepared by Mr. J. M. Westgate, Assistant in Sand-Binding Work, Grass and Forage Plant Investigations, and has been submitted by the Agrostologist with a view to publication.

The six plates accompanying the paper are necessary to properly illustrate the text.

Respectfully,

B. T. GALLOWAY,  
*Chief of Bureau.*

Hon. JAMES WILSON,  
*Secretary of Agriculture.*



## P R E F A C E.

---

The extensive areas of sand dunes which surround Cape Cod Harbor furnish the best example that this country affords of the extensive utilization of beach grass for the binding of shifting sand which would otherwise cause great damage by its encroachment on valuable property. The harbor and city alike are endangered by the shifting dunes which have been encroaching upon them since the original devastation of the forests which formerly held the sands in check.

For a century and a half beach grass has been utilized for sand-binding work upon the cape by the Commonwealth of Massachusetts and by the General Government for the purpose of protecting Cape Cod Harbor, but it was not until 1893 that the State of Massachusetts put in operation the present extensive system of reclamation, which has proved so successful. The Province lands, upon which these plantings have been made, are owned by the State, and the work itself is under the immediate supervision of Mr. James A. Small.

Since these operations are proving so successful and the methods developed there are applicable in a large measure to other similar areas in this country, Mr. J. M. Westgate, Assistant in Sand-Binding Work, was authorized to visit Cape Cod for the purpose of investigating the details of the work now in progress, and to determine, as far as possible, the causes which led to the devastation, and also the measures which have at various times been taken looking to the reclamation of the shifting dunes. The results of the investigation are presented in this bulletin.

Acknowledgments are due the authorities having the reclamation work in charge for the courtesy shown to Mr. Westgate in providing every means to facilitate his investigations.

W. J. SPILLMAN,  
*Agrostologist.*

OFFICE OF THE AGROSTOLOGIST,

Washington, D. C., May 11, 1904.



## CONTENTS.

---

	Page.
Introduction .....	9
Ecological relations of the vegetation .....	10
Ecological factors.....	10
Mode of deposition of the Cape sands .....	12
Development of the dune range .....	13
Natural reclamation .....	14
Areas receiving gradual accumulations of sand .....	15
Areas not receiving gradual accumulations of sand .....	16
Marshes and bogs .....	17
Early accounts .....	18
Devastation of the established dune areas .....	18
Early conditions incident to the devastation.....	19
Restrictive legislation.....	20
Artificial reclamation of the Cape sands.....	21
Early work of sand control.....	21
Recent work by the State .....	24
Preliminary operations .....	24
Attempts without beach grass .....	24
Utilization of beach grass .....	25
Relative merits of spring and fall planting.....	25
Selecting and transplanting the sets.....	26
Cost of planting .....	27
Present status of the various plantings .....	27
Effectiveness of brush laying .....	28
Efficiency of beach grass for sand binding .....	28
Necessity of ultimate forestation .....	30
Miscellaneous operations on the sand .....	31
Road construction .....	32
Reclamation of small areas .....	32
Commercial utilization of sand .....	33
Development of the protective beach ridge .....	34
The Province lands .....	34
State ownership .....	34
Value of the lands .....	35
Summary .....	35
Bibliography .....	36
Description of plates .....	38

## ILLUSTRATIONS.

---

	Page.
PLATE I. Map of sand areas inclosing Cape Cod Harbor .....	Frontispiece.
II. Fig. 1.—Beach grass forming protective beach ridge. Fig. 2.—Beach grass, showing method of vegetative propagation .....	38
III. Fig. 1.—Set of beach grass suitable for transplanting. Fig. 2.—Transplanting beach grass.....	38
IV. Fig. 1.—Sand dune burying forest. Fig. 2. Beach grass plantations. General view.....	38
V. Fig. 1.—Bayberry bushes without grass protection. Fig. 2.—Bayberry bushes with grass protection.....	38
VI. Fig. 1.—Wind erosion of nonprotected sand. Fig. 2.—Protecting a road through the dunes.....	38

## RECLAMATION OF CAPE COD SAND DUNES.

### INTRODUCTION.

The sand areas at the extremity of Cape Cod comprise approximately 6,000 acres, less than half of which is under the protection of forest covering. The city of Provincetown, with its extensive fishing and shipping interests, is built along a narrow strip of reclaimed land lying in the lee of the inner range of fixed dunes bordering the harbor. The peculiar shape and position of the city bring it into immediate peril should any destructive force be brought to bear upon the adjacent dune areas, or in case of the encroachment of the shifting dunes farther back but in line with the winter winds, which are by far the most efficient in sand movement. The harbor around a portion of which the city is built is even more endangered, as it is surrounded by the sand accumulations which have been washed around the head of the Cape, and the entire border on three sides is threatened with the possibilities of sand encroachment. Many houses now stand where a century ago small boats found convenient anchorage. In fact, certain areas have been filled in several hundred feet during the last half century. The value of the harbor thus endangered can hardly be overestimated. It is the home port of a large fleet of fishing vessels, while as a harbor of refuge its position, capacity, depth, excellent anchorage, and land-locked condition combine to render it one of the most important on the Atlantic coast. As many as 1,000 vessels are said to have been counted at one time in the harbor during the heavy gales which occasionally occur along the coast. The entire portion originally known as "East Harbor" has been rendered worthless by the encroaching sands, a fresh-water marsh marking its original site. Not only is the harbor of great commercial value, but in event of war its position is such as to render it of great strategic importance. During the civil war a portion of the extreme end of the Cape was ceded to the Government. Batteries were established and war vessels were at times stationed in the harbor.

The greater portion of the sand areas inclosing the harbor is owned by the State and designated "Province lands" (Pl. I). This enables the authorities to exercise a more effective surveillance than would be possible were the areas under private ownership.

The problem of controlling the drifting sands of the Cape has concerned the municipal, State, and National authorities for two hundred years, and the extensive planting of beach grass as a means of protection dates back for more than a century.

The physiographic and botanical phases of the subject presented are based upon the writer's personal observations and collections. The bibliography indicates the source of the historical features. Many of the details were derived from an examination of the statutes and town records, together with what could be deduced from local testimony and personal observation. The details of the early work of dune control were obtained from the records on file in the War Department, all the work of harbor protection on the part of the General Government having been under the supervision of that Department.

#### ECOLOGICAL RELATIONS OF THE VEGETATION.

##### ECOLOGICAL FACTORS.

The ecological factors which are of the most importance in the consideration of the sand-dune areas are light and heat, wind, soil, and moisture. The low specific heat of the sand causes it to respond very quickly to any change of temperature in the surrounding medium. The sand becomes excessively hot on the side of the dune exposed to the direct rays of the sun and for the same reason the cooling process at night is quite as marked. The extremes of temperature incident to this condition are severe upon any form of vegetation and probably constitute the chief reason for the absence of many species which might otherwise be present. The oceanic location of the area tends to produce an equable climate. The thermometer rarely registers temperatures below 2° F. in winter or above 85° F. in summer, except immediately upon the bare sand areas, where the conditions are much less equable.

The wind is an important factor for several reasons. Its effect upon transpiration, especially when augmented by the high temperatures incident to the heated layers of air at the surface of the sand, is very marked. The distortions of the trees so often noticeable along the coast are not present, as the rejuvenescence of extensive forested dunes has destroyed the woody vegetation to beyond the limits of the injurious effect of the unbroken salt-laden winds. The bombardment by the sand which the wind hurls against the vegetation is especially severe. The presence of sand as large as wheat grains (one-eighth to one-sixth inch in diameter) in great quantities on the dunes testifies to the force of the winter gales which swept it there from the beach below. The force of this bombardment may be realized when walking across a dune area during a strong wind or by examining the effect of the sand blast upon the windward side of the exposed vegetation.

The action of the wind in shifting the sand and thereby either uprooting or burying the vegetation is one of the most obvious points to be noted in a shifting dune area. The heavy winter winds, usually from the northeast or northwest, are the most effective in shifting the sand and in preventing the existence of vegetation. A much more meager vegetative covering is present on the northern than on the southern slopes of the partially established dunes.

The isolated location of the area is such as to subject it to the unbroken force of the winds. The average hourly velocity of the wind for Nantucket, where records are accessible, is 11.7 miles per hour. Gale velocities of from 50 to 60 miles per hour are not infrequent, while velocities as high as 72 miles per hour have been recorded.

The soil of the entire area is largely reassorted glacial sand, at least 95 per cent of which is light-colored quartz. The other constituents are principally magnetite, limonite, feldspar, schist, and garnet. The vigorous growth of the vegetation in the protected locations indicates that the sand is not as deficient in food salts as is sometimes supposed. The large size and angularity of the grains constitute the characteristic features of the Cape sands. It is noticeable that on the bare wind-swept slopes the dune sand has been swept away, leaving the coarser grains, which remain and act as a protective blanket, thus reducing the movement of the underlying sand by the wind.

The following table indicates the size of the two kinds of sand. No. 1 was taken from the surface of the windward slope of one of the dunes. No. 2 was taken from 8 inches beneath the surface of a typical dune and fairly represents the bulk of the Cape sands.

Diameter.	Sample No. 1.	Sample No. 2.
	Per cent.	Per cent.
6-2 mm .....	64.6	00.0
2-1 mm .....	27.9	16.8
1-0.5 mm.....	7.5	77.0
0.5-0.25 mm .....	0.0	5.2
0.25-0.05 mm .....	0.0	1.0

The moisture relations of the dune vegetation are unique. Though the upper layers of sand are usually hot and dry during the growing period except when rain is actually falling, the moisture comes to within a few inches of the surface, even during periods of protracted drought. The effect of a heavy rain is not noticeably different from that of a very light one, as in either case a few hours of sunshine suffice to remove all visible traces of the precipitation, most of which percolates at once to the lower layers of sand. For this reason the number of rainy days, which averages 96, is of greater moment than the actual annual precipitation of 43 inches, which is sufficient under proper soil conditions to produce a luxuriant vegetation. The snows which

might afford considerable protection to the vegetation of the sand stretches are blown off and lodged in the lee of the dunes or within areas covered with vegetation. The humidity incident to the oceanic location of the Cape acts in favor of the existing vegetation. The average annual rainfall is 42.58 inches. The accompanying table indicates the normal monthly precipitation as compiled from the normals for neighboring stations.

	Inches.		Inches.
January .....	3.90	July .....	2.89
February .....	3.39	August .....	3.62
March .....	3.98	September .....	2.91
April .....	3.41	October .....	4.00
May .....	3.62	November .....	4.38
June .....	2.74	December .....	3.74

The factor of associated vegetation or the interrelations of individuals and species is of little importance in areas of shifting sands. The conditions do not admit of a closed formation, that is, where the vegetation completely covers the ground, and it is only when this does finally obtain that the factor assumes an important rôle in the plant society.

#### MODE OF DEPOSITION OF THE CAPE SANDS.

The arm of the Cape extending around Cape Cod Bay consists of glacial deposits, with the exception of about 10 square miles which is composed entirely of post-Glacial sand which has subsequently washed around the head of the Cape from the south, inclosing the harbor within a sickle-shaped sand hook.

The addition of sand to the extremity of the Cape apparently takes place in the form of successive bars, which are built up off the north shore and added to the Cape by deposition in the neck of the channels lying to the east and south, forming successive "race runs" (Pl. I), which are gradually filled in by tide and wind deposits. The sand cast up by the waves on one of these new beaches is dried and blown inland, forming a beach ridge or foredune and eventually a dune range, which, protected by the succeeding deposits, ultimately becomes covered by the forest and associated vegetation.

The above hypothesis is supported by the following observed facts: (1) Four old dune ranges now forested but badly distorted by the long-continued action of the wind; (2) three dune ranges held only by beach grass and lying north of the first-mentioned ranges, parallel with them and also with the north shore of the Cape; (3) a race run (now nearly filled in) with its flanking beach ridge fast becoming a conspicuous foredune (Pl. I and Pl. II, fig. 1); (4) a bar in present process of formation offshore and to northward of the present shore line but parallel with it; (5) the seven dune ranges indicated constitute the

main body of the extremity of the Cape; (6) the presence of shingle or coarse beach deposits underlying the dunes in places, and on the same level with the present beach.

If this be the method of deposition it follows that the necessity for sand fixation will never cease unless the sand supply for the shore drift becomes exhausted. However, the process of sand accumulation is so comparatively slow as to be of little importance when compared with the more serious conditions incident to the extensive areas of only partially reclaimed sand dunes.

#### DEVELOPMENT OF THE DUNE RANGE.

It is probable that each of the seven dune ranges which constitute the greater portion of the extremity of the Cape was developed in a similar manner, from the successive beach ridges and ensuing fore-dunes, by the accumulation of the sands blown up from the beaches. The vegetation has been an important factor in their formation, and although the intermediate stages between the foredune and the forested dune range are fragmentary the general sequence of events is evident.

As soon as the sand deposited by the waves is blown up to beyond the action of the tides the beach grass, associated with the typical strand vegetation, spreads rapidly over the surface and retards the movement of the resulting beach ridge. As the sand accumulations continue, the ridge becomes a foredune. The beach grass pushes its way up through the accumulating sand by the formation of new root-stocks, thus keeping the ever-increasing area of sand comparatively well covered, as the gradual addition of sand constitutes one of the essential conditions for the ideal growth of the grass (Pl. II, fig. 1). The foredune continues to rise and other species of plants come in, but ultimately a height is reached where the unbroken winds are of sufficient force to prevent the vegetation from holding the sand. At this stage the long foredune becomes a dune range and begins to move inland, covering the preexistent vegetation in its path (Pl. IV, fig. 1). The movement continues until the dune range is sufficiently removed from the unbroken force of the ocean winds to permit the development of a vegetative covering dense enough to prevent its movement. The forested condition ultimately dominates.

The development of the succeeding beach ridge and foredune may have been rapid enough to afford some protection to the preceding dune range, and thus hasten its fixation by the vegetation which would develop more rapidly under the protection afforded by the new fore-dune.

This beach ridge is of two possible origins. It may be formed from the normal sand accumulations cast up by the waves along the old beach, after the dune range migrates inland, or it may develop from the sand spit or bar which is added to the mainland as first indicated.

In either case it exerts the same protective influence on the inland vegetation. It may or may not remain stationary long enough for the forest in the lee to reach its farthest possible extension seaward before its rejuvenescence causes it to begin its migration inland.

The movement inland on the part of the newly formed dune range was probably never extensive, as there is little evidence of its having encroached upon the preceding range. However, the contour of each indicates that it was shifting to some extent before its fixation. It is quite probable that the ranges were never entirely bare, as the new accumulations of sand were not so rapid as to prevent the existence of a partial vegetative covering upon the dune range.

The devastating activities within historic times have destroyed any intermediate stages which may have existed between the foredune at present in process of formation on the north shore and the forested dune ranges which lie inland from the three dune ranges which have been devastated by human agencies. It is probable that the forest was never able to develop as far as the beach, owing to the exposure to the severe north winds. However, old forest beds outcropping in places among the unforested dunes demonstrate that the forest originally extended much farther seaward than it does at the present time.

Of the seven dune ranges constituting the body of the extremity of the Cape, only the inner four are at present forested. These are badly distorted, but were probably formed as has just been indicated, as the irregularities are not greater than could be reasonably postulated when the action of the wind during the interval of time which has elapsed since their formation is considered (Pl. I). These ranges are covered with a growth of pine and oak, with an occasional beech in the more favored situations. The outer three ranges are covered with scattering growths of beach grass. The depressions between the ranges are characterized by wild or partially reclaimed cranberry bogs and the associated vegetation. It is probable that all these ranges, with the possible exception of the outer one, were at one time forested, but have been brought to their present unstable condition within historic times.

#### NATURAL RECLAMATION.

The natural reclamation of sand areas may be observed in the study of the series of dunes in the various stages of fixation or establishment by the native vegetation. The forest which ultimately obtains is unable to develop directly upon the bare sand areas. There are certain definite stages that must be passed through before the mesophytic conditions incident to the forest are attained. The vegetation of each stage requires more favorable conditions than did that of its predecessor and at the same time is making the conditions possible for the existence of the vegetation which characterizes the succeeding stage. Even

when the forest condition is reached the cycle is not complete, for the presence of the ultimate climax forest species is possible only after the continued existence of other species of trees has gradually rendered the soil, moisture, and protection sufficiently favorable for the development of the climax type. The ultimate forested condition is the same whether the original area be a salt marsh or a shifting dune, and the sand areas under consideration show several types of reclamation which differ in the initial stages.

#### AREAS RECEIVING GRADUAL ACCUMULATIONS OF SAND.

These areas are confined principally to the depositing beaches and are of less relative importance at the present time than formerly. The strand plants form a zone just above the action of the tides. The sea rocket (*Cakile edentula*), beach pea (*Lathyrus maritimus*), and cocklebur (*Xanthium echinatum*) may be mentioned as typical species. These strand plants are effective in retarding the sand which is blown inland from the beach. They also act as pioneers to the succeeding vegetation which dominates when the original area has become built up sufficiently far beyond the action of the tides to permit the development of another strand or beach formation below the one just indicated. Beach grass (*Ammophila arenaria*) is the dominant species, and extends itself to well within the limit of the wave action during the winter storms (Pl. II, figs. 1 and 2). This is associated with seaside golden-rod (*Solidago sempervirens*) and sand wormwood (*Artemisia caudata*).

The bayberry (*Myrica carolinensis*), wild rose (*Rosa lucida?*), and beach plum (*Prunus maritima*) may be taken as typical of the shrub vegetation which encroaches upon these areas from the wooded stretches lying inland. These, by their presence, increase the humus content of the soil and furnish the necessary protection for the development of the seedlings of the pitch pine (*Pinus rigida*) which soon extend themselves over the partially reclaimed areas. Later the oaks (*Quercus rubra* and *Q. velutina*) become associated with the pine, and in especially favored situations the beech (*Fagus americana*) ultimately dominates. The few areas which have reached this last stage present a somewhat unusual condition. As the beech represents the extreme mesophytic type of forest growth in the northeastern United States and normally grows only in the presence of the most favorable edaphic conditions of soil, moisture, and exposure, the development of the beech formation upon the sand dune is of rare occurrence. The great bulk of the present forest covering consists of the pine and oak, although the white birch (*Betula populifera*), white oak (*Quercus alba*), and red maple (*Acer rubrum*) are to be observed in the lower areas.

The undergrowth within the timbered area consists largely of ink berry (*Ilex glabra*) and huckleberry (*Gaulussia resinosa*). The wintergreen or checkerberry (*Gaultheria procumbens*) forms an extensive substratum below the two species just mentioned, while the hog cranberry or bearberry (*Arctostaphylos uva-ursi*) forms extensive mats where the undergrowth of shrubs is more open. The two grasses, *Agrostis hyemalis* and *Danthonia spicata*, are abundant, forming scattered clumps throughout the open woodlands. Less important but characteristic species of shrubs and vines occurring in the forests are green brier (*Smilax rotundifolia*), bayberry (*Myrica carolinensis*), service berry (*Amelanchier botryapium*), Virginia creeper (*Purthenocissus quinquefolia*), dwarf blueberry (*Vaccinium pensylvanicum*), and coast arrowwood (*Viburnum venosum*). Several species of wild rose are to be noted in the more open places in the forest and along its borders.

#### AREAS NOT RECEIVING GRADUAL ACCUMULATIONS OF SAND.

If, instead of receiving the gradual accumulations of sand, an area is subjected to the eroding action of the wind or at least fails to receive additions of sand, the early stages are quite different from those which characterize the areas just mentioned. The reclamation process at first is very slow, for the heavy winds frequently destroy the work of a whole season and the reduced vigor of the plants incident to the conditions renders the process of humus accumulation extremely slow. The beach grass as before is the pioneer and continues to occupy the area for some time, although not showing a thrifty growth. The poverty grass (*Hudsonia tomentosa*) formation gradually develops and often nearly covers the ground with its procumbent herbaceous stems. This condition continues for some time before there is sufficient humus accumulation for the next members of the cycle. At this stage the bearberry or hog cranberry (*Arctostaphylos uva-ursi*) appears and extends its mat-like evergreen growth over large areas. This is associated with such species as *Polygonella articulata* and *Corema conradii*. These are followed by the bayberry and the beach plum. The ensuing development is substantially that cited for the areas receiving gradual accumulations of sand, as when the formation becomes closed in the two instances there is no further opportunity for either the addition or removal of sand, and hence the initial differences no longer obtain.

As indicated above, the succession of stages from the accumulating beach to the forest was probably the one which characterized the development of the vegetation upon the original sand areas of the Cape. As the deposition of the sand was comparatively slow the vegetation was able to keep pace with the increments, thus preventing the

existence of any extensive sand wastes. The devastating influences which have been brought to bear upon the forested dune areas within historic times have resulted in the extensive areas of loosely bound sands which, with the exception of the brows of the shifting dunes, are for the most part subject to wind erosion. This renders the latter system of natural reclamation most important at the present time. It may be doubted if this system of natural reclamation would be able to reforest the extensive wastes of sand were it not for the artificial reclamation processes which have recently been inaugurated.

#### MARSHES AND BOGS.

The accumulation of sand incident to the formation of the sand hooks or spits has caused considerable areas of salt marshes to be developed (Pl. I). The shifting sands have prevented the establishment of any natural drainage system, and as a result there are extensive areas of ponds and marshes between the dune ranges. These two processes have been the cause of the existence of extensive marsh and bog lands throughout the area. The sand hook which exists at the extreme point of the Cape inclosing the harbor is bordered by an extensive salt marsh. The typical marginal species is saltwort (*Salicornia ambigua*). The characteristic grasses of the salt marsh are the salt reed grass (*Spartina polystachya*) and the salt meadow grass (*Spartina patens*). These grasses constitute the bulk of the salt-marsh hay cut for the local market.

The salt marsh at the head of the old race run at the northwest corner of the sand areas is being gradually filled in by tide and wind deposits. The *Salicornia-Juncus-Scirpus* formation gives way to extensive areas of cranberry (*Oxycoccus macrocarpus*).

Clapp's Pond, one of the fresh-water ponds and marshes lying between the dune ranges, presents over a considerable portion of its surface a sphagnum bog society. Among the characteristic species may be mentioned *Sphagnum acutifolium* (?), pitcher plant (*Sarracenia purpurea*), *Kalmia angustifolia*, and *Xolisma ligustrina*. The margins of the bog are shallow and are rapidly giving way to the encroaching forest. Young pitch pines were noted as extending for a considerable distance into the margin of the bog.

In the low, moist areas between the nonforested dune ranges the cranberry is dominant, occupying large areas to the exclusion of other species. These areas are surrounded by a scattered growth of *Cyperus grayi* and *Carex silicea*. The condition indicated is not permanent, for if undisturbed the woody growth eventually dominates to the exclusion of the above-named species and the forest condition ultimately develops. The improvement and utilization of the cranberry bogs often necessitate the removal of large numbers of bushes which

are present as forerunners of the forest. The order of the succession of the woody plants is practically the same as that given for the other classes of sand areas, except that the beach plum is not conspicuous. It is these low areas that constitute the nuclei of the forests, as it is here that they first develop and then gradually extend to the higher areas. This fact, as will be mentioned under the development of cranberry bogs, constitutes the chief reason for the State's objection to the utilization of these areas for this purpose, as it retards the natural development of the forested condition desired by those who have the preservation of the harbor in mind.

While it is not probable that all of these low areas will ever become entirely forested, yet it is evident that this is the stage to which the low areas, as well as the dunes, are slowly trending. The recent reclamation processes will hasten this condition as the encroachment of the dunes has been checked.

#### EARLY ACCOUNTS.

The early accounts of the New England coast, dating back to the earliest French and English explorers, and possibly even to the Norsemen, essentially agree in their descriptions of the general outlines and forested condition of the Cape. The wooded area appears to have been much more extensive at those dates than at present, although there has always been, at least within historic times, more or less shifting sand exposed to the action of the winds. Champlain in one of his voyages described the Cape and named it Cape Blanc on account of the white color of its sand areas.

The old forest beds, now for the most part covered with sand, but outercopping in places, demonstrate that the wooded areas, at least three times, extended much farther toward the north side of the Cape than they do at present. The tree stumps visible at low tide near Wood End light-house substantiate the local tradition that the forest extended well out on to the extreme point of the Cape a century and a half ago. It is safe to say that at least three-fourths of the non-forested sand areas of to-day were well covered with trees within historic times. However, the devastation is not so marked as it was three-quarters of a century ago, at which time extensive reclamation processes were inaugurated.

#### DEVASTATION OF THE ESTABLISHED DUNE AREAS.

The principal causes of the rejuvenescence of the sand areas and the incident encroachment upon the forest were the pasturing of stock and the partial destruction of the forest covering. The early statutes show many instances where these practices were forbidden under heavy penalties. Much of the injury has been due to fires, as is

evidenced by the charred stumps and charcoal beds which outcrop in places among the devastated dune areas.

The forests close to the harbor were naturally assailed at an early date by the inhabitants and shipmasters, who found the timber a convenient source of certain necessary supplies. The salt factories, which originally constituted an important industry on the Cape, used wood for fuel for evaporation purposes until the beginning of the last century when the more economical method of sun evaporation was introduced. This caused the destruction of large quantities of timber, as did also the extensive production of pitch and turpentine, and the use of the wood on the part of the inhabitants for fuel, fish flakes, ship repairs, and other purposes.

The pasturing of cattle upon the scattered clumps of *Agrostis hyemalis* and *Danthonia spicata* in the more open places in the forested area and upon the beach grass on the outer dune ranges appears to have been a very potent cause of much of the rejuvenescence.

The more recent devastating influences have been much less important. It is still the custom to cut certain areas of beach grass for hay. Until recently it was the practice to cure much of the marsh hay on the adjacent beach ridge which has been artificially built up by the Government as a harbor protection. This process resulted in the killing out of much of the beach grass by smothering it in event of rain, owing to the consequent nonremoval of the marsh hay. The removal of sods for reclamation work within the city limits has caused some concern to the authorities, as has also the utilization of the low areas for the production of cranberries, but, even in the aggregate, these activities are relatively unimportant when compared with the early devastation of the established dune areas.

#### EARLY CONDITIONS INCIDENT TO THE DEVASTATION.

The conditions incident to the devastation of the forested areas appear to have been most severe about a century ago. Many of the houses were constructed on piles to allow the sand to sweep under rather than to accumulate and bury them. Large amounts of sand were artificially removed to prevent the burial of the houses. The sand blast was so severe at times as to completely etch the glass in the windows in a comparatively short space of time. At that time the road led along the beach at low tide and at high tide the travel was through the heavy sands farther up on the beach. The streets were of the same loose sand that everywhere abounded, and it is stated that it was not until the last century that a plank walk was constructed along one side of the principal street of the town.

The committee which was appointed in 1825 to investigate the conditions at Provincetown reported that the trees and beach grass had

been cut down and destroyed on the seaward side of the Cape, allowing the sand to become loosened and driven in great quantities toward the harbor. The report also states that—

The space where a few years since existed some of the highest lands of the cape, covered with trees and bushes, now presents an extensive waste of undulating sand.

The filling up and consequent destruction of that part of the harbor known as East Harbor was the work of the drifting sands to the northward, a fresh-water marsh now marking its original site. As an instance of the effects of the rejuvenated sand areas it may be stated that several once valuable farms situated along Stouts Creek, near Truro, have been covered with sand and to-day there is no trace of even the creek to indicate the location of the original properties.

#### RESTRICTIVE LEGISLATION.

The devastated sand areas at the extremity of the Cape have been the object of State and local concern since the earliest days of its settlement. Accounts state that as early as 1703 local public measures were taken to prohibit the destruction of timber on the "East Harbor lands."<sup>a</sup> In 1714 the devastation incident to the boxing and barking of pine trees for the production of pitch and turpentine had become so extensive upon the sand areas at the extremity of the Cape as to be at that date prohibited by State statute.

It was originally the practice on the part of the inhabitants farther south along the Cape to allow a considerable number of cattle to range over the northern extremity. As the grass growing in the timbered areas was limited, the stock was forced to subsist to some extent upon the beach grass, which then as now covered considerable areas of the Cape sands. An act was passed in 1740 prohibiting this practice and providing for the impounding of the stock found at large upon the lands. In 1745 the destruction of timber within half a mile of the shore was prohibited under penalty. These acts, however, were not as effective as their framers had hoped and were reenforced at intervals.

In 1825 the devastation had become so extensive that commissioners were appointed by the State to investigate the conditions. Their suggestions resulted in an act to prevent the unrestricted pasturage of stock and the destruction of beach grass and woody growth either by pulling or cutting. The enforcement of this measure, together with the reclamation processes inaugurated at this time, materially reduced the devastation which at this period was probably the worst in the history of the Cape.

In 1838 Provincetown was required to elect annually a committee of three persons: (1) To enforce the existing laws regulating the Province lands; (2) to grant permits for the use of portions of these lands by

<sup>a</sup>Massachusetts House Doc. 339, p. 49.

various inhabitants of the town when such use was not detrimental to the safety of the harbor or the town; (3) to enter any of the Province lands, inclosed or uninclosed, for the purpose of setting out trees or beach grass. The cost of the planting was to be defrayed by the occupant of the lands if the necessity for planting resulted from his actions; otherwise the town was authorized to provide for the expenses incident to the planting operations. This was known as the "beach grass committee," and it continued in existence until 1893, when the reclamation work by the State required the appointment of a superintendent on full time.

In 1854 an act, reenforced in 1869, was passed, appointing an agent to prosecute for the penalties prescribed for the destruction of the vegetation. He was authorized to issue permits for pasturage and the removal of sod and brush where the same would work no injury to the harbor or other property. The beach grass committee was continued with the indicated curtailment of its duties. This act became practically noneffective. With the extensive population so close to the public forests and only one person to defend them, it is not surprising that the removal of timber and sod should have proceeded almost without interruption. In 1891 the agent was paid for only five days' services and he issued but four permits. No attempt was made to prosecute parties for the removal of sod without a permit. This constitutes only another instance of the difficulty of enforcing a law in the face of opposing public sentiment.

In 1893 the inhabitants of Provincetown were ceded the lands lying within and adjacent to the city limits, the State retaining possession of what to-day constitutes the Province lands (Pl. I). A superintendent of the Province lands was appointed to look after the interests of the State and to take charge of the reclamation processes at that time inaugurated.

#### **ARTIFICIAL RECLAMATION OF THE CAPE SANDS.**

##### **EARLY WORK OF SAND CONTROL.**

Although at as early a date as the beginning of the eighteenth century there was considerable local concern for the devastation of the sand dune areas, there does not appear to have been much work, other than legislative, actually performed until after the middle of the same century. It was at this time, when the sea broke through to the cove inlet in the arm of the Cape at East Harbor and threatened to destroy the entire Cape Cod Harbor, that the extensive planting of beach grass was commenced. This grass, used in connection with brush fences, repaired the break, and in the course of a few years caused extensive accumulations of sand. It appears to have been the practice upon the part of the inhabitants of Truro to devote a specified time

each year to the planting of beach grass. The aggregate effect of this regular and combined effort was quite marked, although it is always difficult to estimate the results of measures more or less protective in nature. In 1826, as a result of the report of the commission appointed by the State the preceding year to investigate the devastation of the lands surrounding the harbor, the General Government inaugurated an extensive and systematic attempt at the reclamation of the exposed sand areas by the planting of beach grass.

The operations required appropriations extending over a period of twenty-eight years and aggregating the sum of \$36,350. Of this amount it is reported that \$29,889.06 was spent in planting 1,403 acres of the barren sand areas with beach grass. It was soon found that it was best to first plant the areas lying farthest to the windward, as these constituted the source of the sand and the spreading of the grass by seed over the unplanted areas would be facilitated. The actual planting operations were commenced in 1830, and the bulk of the plantings was made between this date and 1839. The grass was brought from Truro in boats and planted at intervals of from two to three feet, depending upon the exposure to the winds. Most of the grass was set with the aid of a shovel, two men working together, although in the low places a pike provided with a crossbar 15 inches from the point proved an excellent tool, as deeper planting was possible and but one man was necessary. This method was found to be impracticable in dry sand, as the small holes filled with sand before the sets could be inserted. Mr. Asa S. Bowly was the superintendent during the greater portion of the time. Spring planting was the rule, and about two hundred acres were planted each season, requiring a force of fifty laborers.

In 1852 the planting was resumed, this time for the purpose of strengthening the narrow arm of the Cape separating East Harbor from the ocean. At this time there was an abundance of grass within the old plantations available for transplanting, although the grass on certain areas had been buried, while in others it had been uprooted by the wind. As a rule the grass on the higher elevations had suffered the most and it was thought best to confine the plantings to the lower areas. The spreading of the grass was facilitated by prohibiting the pasturing of cattle upon the Province lands.

The General Government has spent to June 30, 1903, the sum of \$162,019.86 for the protection of the harbor. Aside from the amount expended for grass planting, this has been used for dikes, bulkheads, and groin fences to catch and hold the sand in place. It has always been the practice to plant beach grass for the purpose of accumulating sand along the dikes and bulkheads, thus increasing the protection afforded by them.

The work of the State was principally confined to legislative acts until the recent work was begun in 1893. It should be stated, however,

that in 1868 the sum of \$131,770.14 was expended in the construction of a dike across East Harbor for the purpose of protecting the remaining portion of the harbor from the large quantities of sand which were carried out by each ebb tide. This dike greatly facilitates the travel southward from Provincetown and is utilized by the railway and State road. The city of Provincetown was authorized to levy taxes to cover the expenses incurred by its beach-grass committee, but an examination of the general records failed to reveal any considerable expenditures by the committee, which was nominally continued until 1893. The regular annual work on the part of the inhabitants of Truro in the planting of beach grass was probably a potent factor in reducing the evil effects of the shifting sand. The independent work on the part of private citizens was on a very small scale. In one instance a number of cranberry growers combined efforts for the purpose of planting beach grass to protect their bogs from the encroaching sand.

There are not sufficient data at hand to render possible a just opinion concerning the effectiveness of the early work of sand reclamation. The devastation is much less than when reclamation processes were commenced, but it is difficult to state to what extent the natural reclamation processes, unassisted save possibly by the restraining but poorly enforced statutes, are to be credited with the change in the conditions.

The grass plantations along the bulkheads, designed to accumulate sand for the protection of the harbor from the sea, have, without apparent exception, been successful. The plantings to restore the breach caused by the sea breaking over into East Harbor resulted in perhaps the greatest single success of any of the earlier operations. The fact that two-thirds of the nonforested areas were covered with beach grass by the end of the last century indicates that the early plantings were probably more lasting in their effect than has been supposed (Pl. IV, fig. 2).

One criticism made is to the effect that the planting was too much confined to the high hills, where it was without protection and as a result the grass was uprooted and destroyed. The statement concerning uprooting indicates that possibly the plantings were too thin, as the plantations recently made on the same exposed places have as yet shown little tendency to be blown out. Perhaps the most just criticism that can be made of the plan of operation is that the woody plants were not introduced within the grass plantations. The life of the beach grass on the areas not receiving regular accumulations of sand seldom exceeds ten years, a period of time which, however, suffices for the establishment of a self-protecting plantation of bushes and tree seedlings which require but little subsequent attention to render the reclamation permanent.

## RECENT WORK BY THE STATE.

## PRELIMINARY OPERATIONS.

The artificial reclamation which had been prosecuted with more or less vigor during the first half of the last century apparently received but little attention until 1892, when the trustees of the public reservations were authorized to submit all available information concerning the status of the sand encroachments and control, together with a comprehensive plan for the reclamation of the nonforested sand areas that threatened the harbor. The committee made a careful personal examination of the land and presented, with their general report, a stenographic transcript of the proceedings of a mass meeting of the representative citizens of Provincetown and Truro, who presented such information and suggestions as they were able to give concerning the historic features of the sand areas and the most practical steps to be taken for their reclamation. As a result of the trustees' report the Province lands were placed in charge of a permanently employed superintendent, Mr. James A. Small.

The State at this time relinquished its right to the lands within and immediately adjoining the city of Provincetown, leaving but 3,290 acres under State title. Of this area approximately 2,000 acres were nonforested.

Correspondence with various authorities revealed the fact that the initial operations would have to be more or less experimental, owing to the lack of data concerning the previous reclamation operations upon similar areas. Even the available details of the extensive grass plantations made upon the same areas in the early part of the century were purely matters of local tradition.

There was expended during the ten years ending January 1, 1904, the sum of \$31,929.78 for the reclamation of these lands. The following itemized statement has been furnished by the authorities:

Beach grass planting.....	\$10,950.00
Introduction of woody growth.....	6,011.78
Construction and maintenance of roads.....	6,250.00
Superintendence .....	6,000.00
Incidental expenses, including survey.....	2,718.00
Total .....	31,929.78

## ATTEMPTS WITHOUT BEACH GRASS.

The three great dune ranges which lie between the timbered area and the north shore of the Cape were entirely bare upon their northern slopes, and were encroaching at the rate of 15 feet per year upon the forest and toward the city and harbor from a quarter of a mile to a mile distant (Pl. IV, fig. 1). The less exposed areas were partially covered with beach grass, while the lower places were dominated by

native cranberry bogs, surrounded by the characteristic low-growing vegetation. As the bare northern slopes of the dune ranges constituted the source of the sand supply, the initial attempts involved the covering of these areas with vegetation.

Extensive plantings of shrubs and tree seedlings were made upon the outer range of dunes. The result was that the heavy winter gales of the first season buried, uprooted, or killed by the sand blast so great a portion of these plantings that some other method of procedure was considered necessary. The next season the transplanting of beach grass was commenced, as the experience of the preceding season had demonstrated that some protection for the woody plants is necessary until they have made sufficient growth to be self-protecting (Pl. V, figs. 1 and 2). The beach grass was selected for this purpose as it occurs very abundantly in places immediately adjacent to the areas which required planting and had been extensively utilized in the early reclamation attempts.

#### UTILIZATION OF BEACH GRASS.

Grass planting operations on each range commenced on the west end and were extended eastward with more or less regularity. The following table shows the salient points concerning the various plantings, which aggregate 219 acres. The mortality percentages were calculated from a number of counts in several representative areas within each season's planting. The mortality appears to have been less among the fall plantings.

Year.	Acreage planted.		Mortality of plantings, per cent.	
	Spring.	Fall.	Spring.	Fall.
1895.....	11	2	50	31
1896.....	12	4	61	38
1897.....	20	22	40	35
1898.....	3	17	22	11
1899.....	13	22	6	2
1900.....	4.5	15.5	4	2
1901.....	4	21	3	2
1902.....	1	20	1	1
1903.....	2	25	0	0
Total .....	70.5	148.5	.....	.....

#### RELATIVE MERITS OF SPRING AND FALL PLANTING.

The early plantings on the Province lands and the Cape generally were as a rule made in the spring, although many parties practiced fall planting. The plantings incident to the recent work of reclamation have been made for the greater part in the autumn. It is the consensus of opinion that better results follow fall planting for the following reasons: (1) In the fall the growth of the season is finished

and plants are dormant for a considerable period of planting weather. (2) The new rootstocks appear to be more firmly attached than they are in the spring, and are consequently less liable to be broken off during the transplanting process. (3) The days are cooler and the incident evaporation less. (4) It is easier to distinguish prime planting stock, and the rooted nodes lying within a few inches of the surface of the sand may be readily removed by hand pulling; in the spring they are apt to be either buried or exposed by the action of the shifting sands. (5) There is an additional winter of effectual protection to be gained by fall planting, as the dormant sets suffer no deterioration the first winter.

The above table concerning the plantings of the different years and seasons shows a marked difference in favor of fall planting. However, the difference between the two seasons is so slight as to be offset by any practical reason why the spring season should be utilized for planting, as for instance the greater ease in procuring the labor or the necessity of finding nearly permanent employment for the help in order to keep it available when needed. In case the planting is extensive it can rarely be completed in one season, and the planting period is thus practically doubled if the spring as well as the fall season can be utilized.

#### SELECTING AND TRANSPLANTING THE SETS.

The plants selected for transplanting are vigorous and well rooted. This means in practice 2-year-old stock, as the year-old plants are not mature enough or sufficiently rooted to bear transplanting well, as do the older plants. If more than two years old the vitality is likely to be low. As a rule the 2-year-old plants may be readily pulled with the hand and still retain sufficient rootage to enable them to grow when transplanted (Pl. III, fig. 1). It should be mentioned that the hand pulling is not extensively practiced elsewhere in the country, it being the custom to use a spade or shovel in procuring the planting stock. The results indicate that it is largely a matter of opinion as to which method is the better. The plants are piled in bunches and carted to the place where the planting is in progress. Whenever they are to be exposed to the air for any length of time they are heeled in with a covering of moist sand over the roots.

When setting out the grass it is the custom for two men to work together (Pl. III, fig. 2). The one with a shovel inserts it in the sand as far as the foot can force it. A backward pull of the handle loosens the sand at the bottom of the hole, while a forward thrust produces a sufficient opening between the back of the shovel and the sand to allow the insertion of the plant by the second man, who carries an armful of the sets. The man with the shovel by one pressure of his foot packs the sand around the newly set plant. The shovel is inserted a second

time at a distance of about 20 inches from the first, and all is ready for the next set. The planting proceeds quite rapidly, as two men are able to set 600 plants per hour.

#### COST OF PLANTING.

The cost of planting depends upon the thickness at which the grass must be set. On the more exposed areas requiring thick setting five men procuring sets, two teamsters, and eight planters, working nine hours per day, are able to cover an acre in two days. With wages at \$2 per day the cost is approximately \$65 per acre. This is with an abundance of planting stock growing within a mile of the areas to be covered. The thickness of the planting is responsible for the great expense of the operation, but the exposure of the northern slopes to the severe winter gales makes it probable that thinner plantings would prove ineffective, at least upon the most exposed areas. The expense is much less on the more protected areas, where thinner planting suffices, and those having the work in charge state that the 219 acres, covered with grass, have been planted at an average cost of \$50 per acre.

The plantings of the first two years were made in rows ranging from 12 to 18 inches apart with the plants 12 inches or less in the row, but this method appears to be less desirable than the irregular setting which has since been used, as under the latter method there are no uninterrupted channels through which the wind might sweep. The plants are set approximately 20 inches apart, but there is evidence, however, that it is not necessary to set them so close as this, except on the most exposed areas. The thinner plantings afford more rooting area for the sets, and this helps to maintain the vigor of the transplanted sets. The increase in cost of the thick over the thin planting is not justified unless there is considerable advantage to be derived from the former. It has been the custom to protect the plantings with lateral brush hedges. The large branches are set vertically in the ground at intervals of from 2 to 3 feet and the interstices filled with smaller brush. These hedges catch great quantities of sand or in case of wind erosion prevent the uprooting of the grass (Pl. VI, fig. 1).

In some of the areas the small and isolated elevations have been covered at a considerable expense with grass. This has been thought to be an unnecessary procedure, as the wind reduces these elevations, furnishing a gradual accumulation of sand over the plantings on the associated level areas, which instead of proving a detriment to the plantations increases the vigor and vegetative propagation.

#### PRESENT STATUS OF THE VARIOUS PLANTINGS.

The table giving the acreage and mortality shows the salient facts concerning the plantings of the different dates and seasons. There is a uniform deterioration from the time the plants are set until they have

disappeared. This is shown more clearly in Plate V, figure 2, than in the mortality table, for in the latter no account is taken of the great reduction in size and vigor which the sets have undergone. In the plantations of 1895 beach grass and poverty grass (*Hudsonia tomentosa*) from wind-scattered seed are slowly working in among the old sets. It is possible that this natural reclamation process will continue until the entire area is permanently covered with vegetation, although this same site was covered with grass in 1830 and the force of the winds prevented the natural vegetation from establishing itself among the transplanted beach grass. In the plantations of 1899 there are to be noted areas where the grass has retained its natural vigor, although there is no apparent difference between these and the areas showing a less vigorous growth.

#### EFFECTIVENESS OF BRUSH LAYING.

It has been the custom to cover certain areas with brush, usually those at the top of the ranges and just above the grass plantations. These areas were more or less subject to the eroding action of the wind, and it was thought that brush would answer the purpose better than beach grass. The brush was at first laid on in squares, but this proved less effective than the method of placing the brush uniformly over the entire surface; hence the latter system has been adopted. The beach grass comes in from naturally sown seed, and since the sand is not accumulating the grass is more or less depauperate; yet it is able to survive and by the time the brush decays has prepared the way for the succeeding vegetation, which, in connection with the grass, is able to hold the sand quite effectively. The laying of brush has been practiced quite extensively for the protection of roadways through the sand. The total area covered has been about 15 acres, at an approximate cost of \$25 per acre. The addition of a small amount of soil to the area covered with brush has been found to greatly hasten the formation of the vegetative covering. The application need not be continuous nor at all thick. Brush cut with the leaves attached is best, as the humus content of the sand is increased and a much better protection afforded as long as the leaves remain.

#### EFFICIENCY OF BEACH GRASS FOR SAND BINDING.

Although many grasses have been tried at various times and places in this and foreign countries, no other has proved so effective as the beach grass. The long, tough, but flexible leaves of the beach grass enable it to endure the action of the wind with little detriment. A bunch of dead grass will withstand two seasons of wind action without becoming entirely destroyed. The statements sometimes made concerning the sand-binding power of the roots of this grass must be taken with some allowance. The principal place where the sand-binding

action of the rootstocks may be observed is where an area covered with beach grass becomes rejuvenated. Here, the places most thickly overgrown with the grass are the last to be eroded by the wind. The grass stems and exposed rootstocks hanging loosely over the sides of the eroded hillock protect it to a considerable extent and retard its ultimate reduction. So far as observed the rootstocks seldom form a thick mat-like mass sufficiently near the water's edge to be of material assistance in reducing the eroding action of the waves, except in severe storms, when the wave action extends inland for a considerable distance (Pl. II, fig. 1). The chief value of the grass in this instance is the accumulation of sand induced, which, by its presence, keeps the destruction of the property adjoining the water reduced to a minimum.

Beach grass ordinarily requires a gradual accumulation of sand over its crown to induce a normal vigorous growth. It is for this reason that it is to be noted in great clumps protruding from the crest of small dunes, where it has accumulated a considerable quantity of sand each year, but at the same time not enough to cover it so deeply that the new plants are unable to develop. This is due to the fact that when the grass becomes partially buried the sand is no longer held by the protruding grass leaves and it passes over, and the grass is able to renew its growth the following year with increased vigor, since the accumulated sand is permeated with the roots of the new rootstock sent out by the half-buried clump. A healthy growth of beach grass can thrive where the burial by sand is not over a foot per year.

The areas which usually require planting are generally those from which the sand is being removed by the wind rather than those which are receiving the accumulations so essential to the vigor of the grass. For this reason the most that can be expected of the grass is that this sand removal shall be checked as long as the grass is able to survive under the unfavorable conditions, which allow of no accumulation of sand over the plants. The decrease in vigor of the sets from the time they are set out is a matter of common knowledge to those who have noted the plantations of beach grass under these conditions for a series of years. (See mortality table, p. 25.) It appears that this necessity for sand accumulation lies in the fact that it induces the development of new rootstocks by the old plant and thus occupies an unused portion of the sand which presents such a dearth of food salts that these are soon depleted and the deterioration noted must ensue unless new areas of sand are made tributary. Furthermore, there is no power of downward growth on the part of the rootstocks, and as a set rarely possesses more than two nodes the root system is very limited. The new rootstocks developed in the accumulated layers of sand constitute the only means of bringing new supplies of sand within reach of the grass plants. The old rootstock becomes buried, but continues to support to some extent the new plants until sufficiently

established to be able to withstand the rather severe conditions incident to the dune areas. This process continues and the grass is thus continually rejuvenated.

Another reason for the deterioration noted above may be the fact that a single set of grass is not of indefinite existence, and unless it is induced to increase vegetatively it soon loses its vigor. There are areas in the United States where this deterioration subsequent to the transplanting is not manifested. At Grand Haven, Mich., at Coos Bay, Oregon, and at Poplar Branch, N. C., the beach grass has continued to increase in vigor since the plantations were established. This is apparently due to the fact that the plantings were made sufficiently far apart to allow most of the sand to drift through the plantations, thus enabling each set to receive a small amount of sand. This method, however, would be applicable only to limited areas on Cape Cod, as it is the eroding surfaces which require protection. However, these instances indicate that it is possible in certain areas to distribute the sand accumulation and often build up areas that are eroding, and this method should be in mind whenever a plan of attack on the dune areas is under consideration. The great reduction in the cost per acre where this thin planting can be utilized is a decided point in favor of its adoption wherever at all practicable. The cost of the Coos Bay plantations has been only \$8 per acre, 64 acres having been planted in a single season with an appropriation of \$500. In this place the grass was set 4 feet apart, and rather favorable climatic and edaphic conditions have been to some extent responsible for the success of such thin planting.

Trials of other sand-binding grasses have demonstrated the superiority of beach grass for sand-binding purposes under conditions which characterize the dune areas of Cape Cod. In 1901 experiments were made with the sand sedge (*Carex macrocephala*) and seaside bluegrass (*Poa macrantha*). These are very efficient sand binders upon the Pacific coast, and were obtained through the Division of Agrostology from Clatsop beach, near Fort Stevens, Oregon. Neither the seedlings nor the sets of these species proved successful. The seeds germinated well, but failed to survive the winter, as was also the case with the transplanted sets.

#### NECESSITY OF ULTIMATE FORESTATION.

The marked deterioration of the beach-grass plantings shows the need of introducing woody growth among the areas at as early a date as possible (Pl. V, figs. 1 and 2). The various native or imported woody plants should be set out among the grass soon after the grass has been planted, as the first years of the protection afforded by the grass are the best and are, in the aggregate, none too long to enable the shrubs and young trees to make sufficient growth and rootage to be self-protecting by the time the grass deteriorates so as to be

practically valueless. It seems that it is necessary to start such a shrub or bush as the bayberry. This is not injured by the unfavorable conditions, and seedlings of pines and oaks may with safety be introduced among the bushes. Even the planting of the pine seeds and acorns has with this protection been successful.

Several species of woody plants have been tried with varying success. The following have been found to be unadapted to the conditions: Seaside pine (*Pinus maritima*), tree of heaven (*Ailanthus glandulosa*), ironwood (*Ostrya virginiana*), European birch (*Betula alba*), tamarack (*Tamarix gallica*), poplar (*Populus alba*), larch (*Larix* sp.), willow (*Salix* sp.), and privet (*Ligustrum vulgare*). Too much weight should not be given to the unsuccessful attempts with the willow and poplar, as they have made a vigorous growth on the sand within the city limits, and their behavior elsewhere, under almost as adverse conditions, appears to at least justify a more extended trial.

The successful species are comparatively few in number. Of the pines, pitch pine (*Pinus rigida*), Austrian pine (*P. laricio*), and Scotch pine (*P. sylvestris*) are proved successes. The pitch pine is used most extensively, as it grows naturally in the adjacent forests, and young trees and cones can be obtained in almost unlimited quantities. The black locust (*Robinia pseudacacia*) and the European or black alder (*Alnus glutinosa*), though not occupying extensive areas, have proved thoroughly adapted to the conditions, and it is the plan to increase the plantings of these two species. The Scotch broom (*Cytisus scoparius*) is well adapted to the conditions with the one exception of not being perfectly hardy, as many small areas have been killed by one or two excessively cold winters, though much of the original planting is still alive and vigorous. The plant does not spread readily from seed, as the severe conditions prohibit its existence in the early seedling stage, and furthermore, the seed being large and conspicuous is readily eaten by birds and small animals. The growth is very dense, and even scattered bunches would prevent the sand from shifting, but its semihardiness makes it decidedly inferior to the bayberry, which is locally abundant, perfectly hardy, and easily transplanted. The bayberry has formed the bulk of the pioneer plantings of woody growth, and used in connection with the beach grass appears to be the only necessary forerunner of the pines.

#### MISCELLANEOUS OPERATIONS ON THE SAND.

Besides the reclamation processes leading to the ultimate reforestation of the dunes, there are a number of other operations which have ameliorated to some extent the adverse conditions incident to the sand dunes. Among these may be mentioned the construction of roads, formation of cranberry bogs, etc., the development of a sod in pastures, cemeteries, and lawns, and the accumulation of sand to form a beach ridge for harbor protection.

## ROAD CONSTRUCTION.

The problem of road construction in sandy regions, and, as a rule, districts with sparse population, is a very difficult one, and is frequently not solved until the demand has long been imperative. The road leading from Provincetown south originally followed the beach at low tide, but at high water the travel was through the heavy sand farther up on the beach. The State is at present constructing a macadamized road extending from Provincetown southward, thus connecting it with the main part of the State. Before the road across the sand areas was macadamized, liberal applications of clay had facilitated the travel for many years.

There are several roads across the Province lands, and where they lead through the forested portion they are in good repair. On the shifting sand areas none but the State road has received much attention, although most of the portions where there is danger of gullying by the wind have received a protective covering of brush (Pl. VI, fig. 2).

The building of the State road across the Province lands was commenced in 1894 and completed in 1901. It extends from the city to the Peaked Hill Life-Saving Station and provides an easy means of access to the heart of the dune territory. The road was not constructed across the dunes area until the shifting sands had been brought under control. The roadbed was first graded and then covered with a layer of brush, after which it received a covering of turf sod obtained from the adjacent woods. It is still in good condition and promises with some attention to be fairly permanent, as it is subject to but little heavy teaming. The cost of construction was about 35 cents per running foot.

When the railroad was constructed the cuts were covered with brush and rubbish, which proved sufficient protection until a natural growth of beach grass developed, and no difficulty has since been experienced from gullying by the wind.

## RECLAMATION OF SMALL AREAS.

Although the State holds the title to the Province lands and the public in general has had free access to its natural products, there are certain areas of the native cranberry bogs which have been staked off and improved by private parties. This was a common practice and many of the berry growers were assessed either on the land or its product. There seems to have been no serious outcome from this procedure except that it generally involved the removal of considerable brush and bushes, thus preventing the development of the forest in the immediate area. This has been the cause of some conflict of opinion with the State authorities, as it is the idea of those that have

the preservation of the harbor in mind that the lands can be controlled with much less expense if the entire area be forested, and it may be said that the present State appropriations for the Cape are to this end. Fires have been started from the careless burning of the brush removed in the process of clearing the bogs. However, it appears that even with State ownership of the land the present prices of cranberries make them a source of little, if any, profit, as the soil is not adapted to producing yields comparable with those farther south along the Cape.

The pasturage of cattle upon the Province lands has long been prohibited by statute, and the pastures in use have been reclaimed from the bog lands near the city. Certain low places have been filled in, and the redtop present forms a close turf and is apparently able to withstand the usual amount of pasturing.

The lee side of an established dune adjacent to the city has been terraced for the purpose of growing strawberries. The necessary substratum for the vines was obtained from the humus accumulation on the side of the dune. As there are numerous similar areas in the immediate vicinity, this indicates the possibilities if due care were taken not to rejuvenate the dunes, and there appears to be little danger of this on the lee slopes.

As with all old places, the cemetery is extensive and its uniformly good appearance is worthy of note, especially when the adverse conditions are considered. The soil rendering the bluegrass sod possible was either hauled in wagons from further south along the Cape or brought by boat from across the bay. A recent addition to the cemetery was leveled off and the bare sand protected with brush and sods, most of which came from the land leveled for the addition. The above statements may also be made concerning the lawns about the residences in the city, as the soil for these had to be imported from the same sources.

#### COMMERCIAL UTILIZATION OF SAND.

The sand, being of varying size, angular, and light colored, is valuable for many purposes, but its exportation appears to have been discontinued. The sand constituting an entire dune was at one time removed to Boston, the ships returning with loads of soil for use on lawns and in the cemetery. A glass factory was once in operation farther south on the Cape, but it, too, has been discontinued. The sand is valuable for polishing and cutting marble and granite, as well as for use in mortar, and in former years "Cape Cod sand" was frequently specified in important contracts for building in cities having navigable water connection with Provincetown. Sand was used in filling in the shallow water at the base of the forested dunes to form

building sites for the business houses and dwellings, as originally there was very little building space along the harbor, which was so shallow near the edge as to make landing difficult.

#### DEVELOPMENT OF THE PROTECTIVE BEACH RIDGE.

The extensive sand flats and marshes associated with the sand hook forming one side of the harbor have always been subject to the inroads of the sea, which threatened the harbor with great incursions of sand. A protective beach ridge has been developed in all of the weaker places on the sand hook. Groin fences, in connection with beach grass, have induced extensive accumulations of sand, which are very effective in protecting the harbor and the bulkheads from the action of the sea during storms. This process of reclamation is in operation at present, the object being to build up a protective beach ridge along the salt marsh near the extreme end of the Cape south and west of Provincetown.

#### THE PROVINCE LANDS.

##### STATE OWNERSHIP.

The Province lands, situated at the extremity of Cape Cod, have had a peculiar history. When the provincial government ceased and Massachusetts became a State, all of the unoccupied lands retained the title of "Province lands," as all the land had previously been designated. It was not until 1893 that the State ceded to the inhabitants of Provincetown even their building sites, although previous to that date they had been privileged to give warranty deeds when making real estate transfers. There exist excellent reasons for State ownership of these sand areas which inclose the harbor, as it is only under such ownership that the necessary attention can be given to render the protection of the harbor efficient. The city and harbor are entirely too important to allow the half-established sand areas which endanger them to pass into the hands of private parties and to be subject to possible shortsighted policies leading to immediate profit.

It seems equally desirable that the State should also own what are known as the "Lotted lands," which constitute the sand areas lying between the Province lands and the glacial deposits comprising the original head of the Cape (see Pl. I). The sand of this area is more loosely bound and the shifting dunes are much nearer the harbor than are the sand areas of the Province lands. The "Lotted lands" are of little economic value and title could be obtained for a nominal consideration. At the present time timber and beach-grass hay are being removed by private persons to supply the local demand for these products. In view of the importance of the property thus endangered these practices need no comment.

## VALUE OF THE LANDS.

Agriculturally and horticulturally the lands surrounding the harbor have little value. No field crops are raised, and the redtop pastures are very small, being for the most part reclaimed bogs with an aggregate area of approximately 25 acres. The salt marshes yield about 200 tons of hay per year, and beach-grass hay to the amount of 15 tons is annually obtained from the sand areas lying just outside of the Province lands. The cranberry bogs, while extensive, are not regarded as especially profitable holdings even with the State owning the lands.

The sylvicultural resources of the lands might possibly be turned into account. The growth of the timber is slow, but the climatic conditions are favorable, and an intelligent system of forestation under existing prices would materially assist in providing for the expenses incident to the supervision of the lands.

It has been suggested that the lands might be improved and brought into the market as building lots for summer cottages, or, this failing of realization, that a game preserve might be established and a revenue derived from shooting privileges. Neither of the projects appears to have met with much favor. The chief value of the lands is as a harbor former, and all plans should conserve to this end.

The idea of converting the area into a marine park has many points in its favor, and it may be stated that those in charge of the land have this project in mind and are working to that end. The isolation, beauty of natural scenery, and oceanic location, with its 5 miles of heavy surf and an equal frontage on the bay, combine to render the locality probably without an equal on the Atlantic coast. The harbor must be protected from the loose sands on the north side of the Cape, and the forested condition necessary for a marine park is exactly what is required by the proposed plans to render the area a permanent protection to the harbor, and the money spent in reclaiming the lands, if applied along landscape-engineering lines, will ultimately produce an ideal ocean park. The successful development of the Golden Gate Park at San Francisco has demonstrated the possibilities of such sandy tracts when properly reclaimed.

## SUMMARY.

The sand areas inclosing Cape Cod Harbor were originally forested, but have been extensively devastated within historic times. Restrictive legislation dating back as far as 1714 has exerted a restraining influence upon the devastating activities. In 1826 extensive reclamation processes were inaugurated, but were unsuccessful owing to the failure to introduce woody plants within the beach-grass plantations. The State in 1893 formulated an extensive plan for the reclamation of these

areas. The initial plantings of woody plants were unsuccessful, owing to their having been introduced into the shifting sand areas without the protection of beach grass. Plantations of beach grass aggregating 219 acres have been made and large numbers of bayberry bushes, young pines, etc., have been introduced among the grass, which persists until the bushes and young trees have attained sufficient size to be self-protecting. The State has expended for reclamation purposes during the ten years ending January 1, 1904, \$31,929.78, of which \$10,950 was for grass planting. The General Government has spent \$162,019.86 in its work of harbor protection, and the total amount expended upon the harbor by the State and National Governments is \$325,719.78. This includes \$131,770.14 expended by the State in 1868 for the construction of a dike across East Harbor.

The sand areas are of vital importance to the harbor and their control necessitates reforestation, which is at present being accomplished, the authorities having in mind the ultimate development of a marine park.

#### BIBLIOGRAPHY.

DWIGHT, T. Travels in New England and New York, 1796 and 1797 (1823).  
Mass. Sen. Doc. No. 5 (1854).

(Being a report on Cape Cod and East harbors.)

FLINT, C. L. Grasses and forage plants (1858).  
THOREAU, H. D. Cape Cod (1864).  
Mass. House Doc. No. 50.

(Being a report on the condition of Long Point and East Harbor.)

Mass. Sen. Doc. No. 5 (1872).

(Being a report on the construction of the East Harbor dike in 1868.)

Annual reports of the Chief of Engineers, U. S. Army, 1876, pp. 181-190; 1879, pp. 273-275; 1886, pp. 574-577; 1903, pp. 87, 783-784.  
Mass. House Doc. No. 339 (1893).

(Being a report on the Province lands authorized under chapter 420 of the acts of 1892.)

SMALL, JAMES A. Reports of the Superintendent of the Province lands. Annual reports of the Harbor and Land Commissioners, 1893-1903.

SCRIBNER, F. LAMSON. Grasses as sand and soil binders. Reprint from the Yearbook of the U. S. Dept. Agric., 1894, pp. 421-436.  
— Sand-binding grasses. Reprint from the Yearbook of the U. S. Dept. Agric., 1898, pp. 405-420.

COWLES, H. C. Ecological relations of the vegetation on the Lake Michigan sand dunes. Reprint from the Bot. Gaz., 27:95 et seq.

HOLICK, A. Geological and botanical notes: Cape Cod and Chappaquidick Island, Massachusetts. Bul. N. Y. Bot. Gard., 2:381-407.

---

---

P L A T E S.

## DESCRIPTION OF PLATES.

PLATE I. (Frontispiece.) Map of the sand areas inclosing Cape Cod Harbor. The 30-foot contour lines indicate roughly the topography and general outlines of the seven dune ranges which constitute the larger portion of the sand areas surrounding the harbor. The outer three nonforested dune ranges have been covered with beach grass and are indicated in black.

PLATE II. Fig. 1.—Beach grass forming protective beach ridge. The grass is shown to extend to within the limit of wave action during the winter storms. Its peculiar habit of sending out rootstocks when buried enables it to keep the ever-increasing sand deposits well covered. The gradual accumulations of sand incident to these depositing ridges form the ideal conditions for the thrifty growth of this grass. The beach ridge indicated has increased 20 feet in height during the past twenty years. The beach grass has been the chief factor in accumulating the sands necessary for the strengthening of this portion of the sand areas protecting the harbor. Fig. 2.—Beach grass, showing method of vegetative propagation. Beach grass is efficient in the natural reclamation processes owing to the method of rapid vegetative propagation from rootstocks, which enables scattered individuals to soon cover the drifting sands with a sufficient growth to prevent the sand movement.

PLATE III. Fig. 1.—Set of beach grass suitable for transplanting. The set shows two nodes of the rootstock with attached rootlets. Two-year-old stock is most desirable for transplanting. The method of hand pulling is practiced throughout these areas. Fig. 2.—Transplanting beach grass. The gently sloping sand areas are covered with beach grass in the manner indicated. The brows of the hills are covered immediately with bayberry transplanted from the adjoining timbered areas. The steeper slopes are often reduced to an angle of 25 degrees or less before the planting is begun.

PLATE IV. Fig. 1.—Lee slope of a sand dune showing the manner in which the advancing dune buries forests lying in its path. Fig. 2.—General view of the grass plantations, looking south. Native growth in foreground. In the background the transplanted beach-grass area adjoins the sands not yet covered. Bayberry bushes have been introduced upon the crests of the dunes. Before these areas were covered with the grass, the dunes were encroaching upon the forest and city shown in the distance.

PLATE V. Fig. 1.—Bayberry bushes without grass protection. The presence of bushes alone is not sufficient to prevent the shifting of the sand. The large size of the sand grains is indicated in the foreground. Fig. 2.—Bayberry bushes with grass protection. The deterioration of the grass is evident but its duration is sufficient to enable the introduced woody growth to become self-protecting. The grass was planted in 1898 and the bayberry a year subsequently.

PLATE VI. Fig. 1.—Wind erosion of nonprotected sand. The brush line in the center marks the eastward extension of the beach grass plantings of 1898. The amount of sand erosion by the wind since the grass was introduced is clearly indicated on the eroded sand areas at the left where it appears that at least 15 feet of sand have been removed. Fig. 2.—Protecting a road through the dunes. The brush lines, logs, and bushes form an efficient protection to the sides of the cut. The roadbed consists of brush overlaid with turf sods obtained from the neighboring forest.





FIG. 1.—BEACH GRASS FORMING PROTECTIVE BEACH RIDGE.



FIG. 2.—BEACH GRASS, SHOWING METHOD OF VEGETATIVE PROPAGATION.





FIG. 1.—SET OF BEACH GRASS SUITABLE FOR TRANSPLANTING.



FIG. 2.—TRANSPLANTING BEACH GRASS.





FIG. 1.—SAND DUNES BURYING FOREST.



FIG. 2.—BEACH GRASS PLANTATIONS—GENERAL VIEW.





FIG. 1.—BAYBERRY BUSHES WITHOUT GRASS PROTECTION.



FIG. 2.—BAYBERRY BUSHES WITH GRASS PROTECTION.

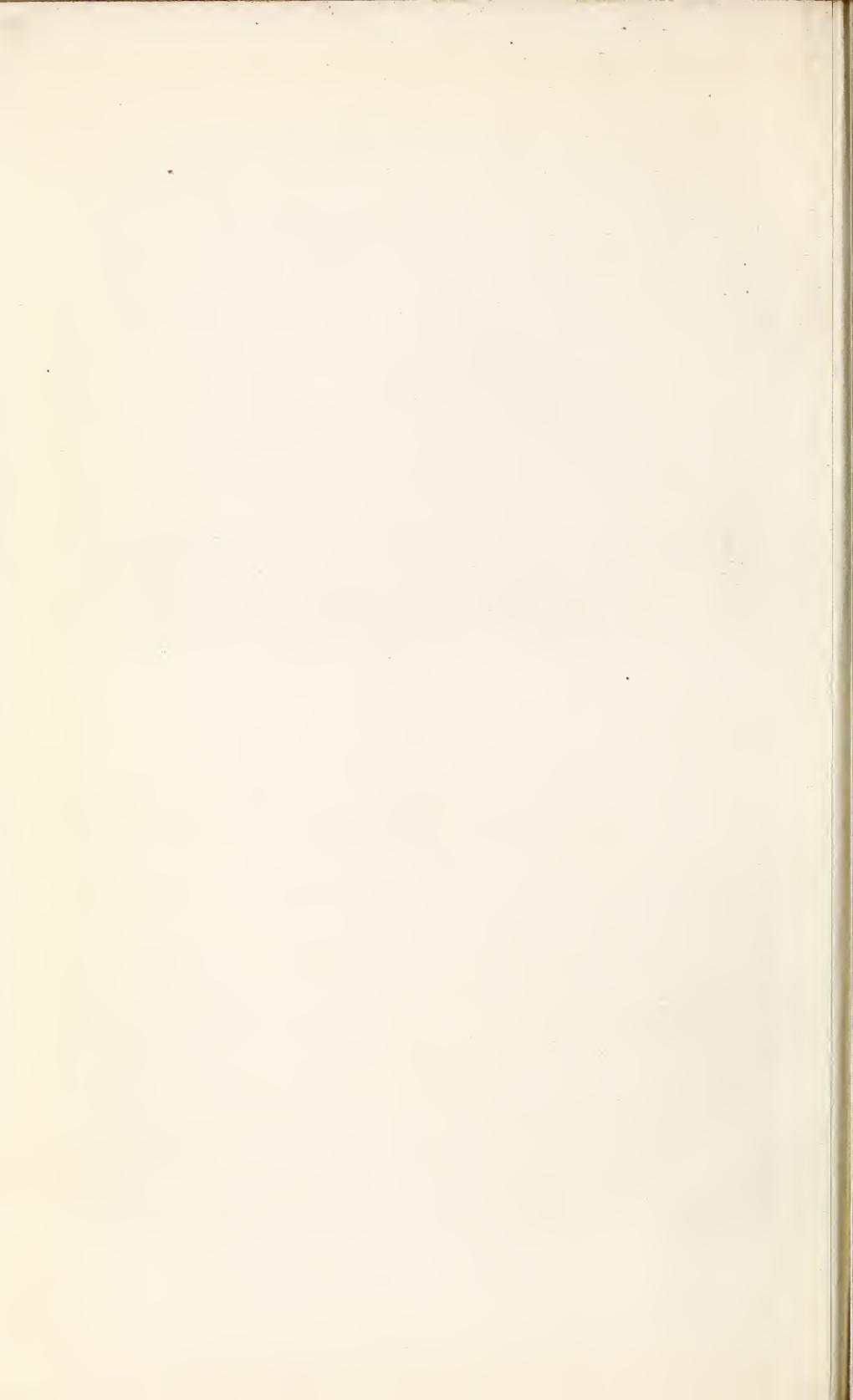
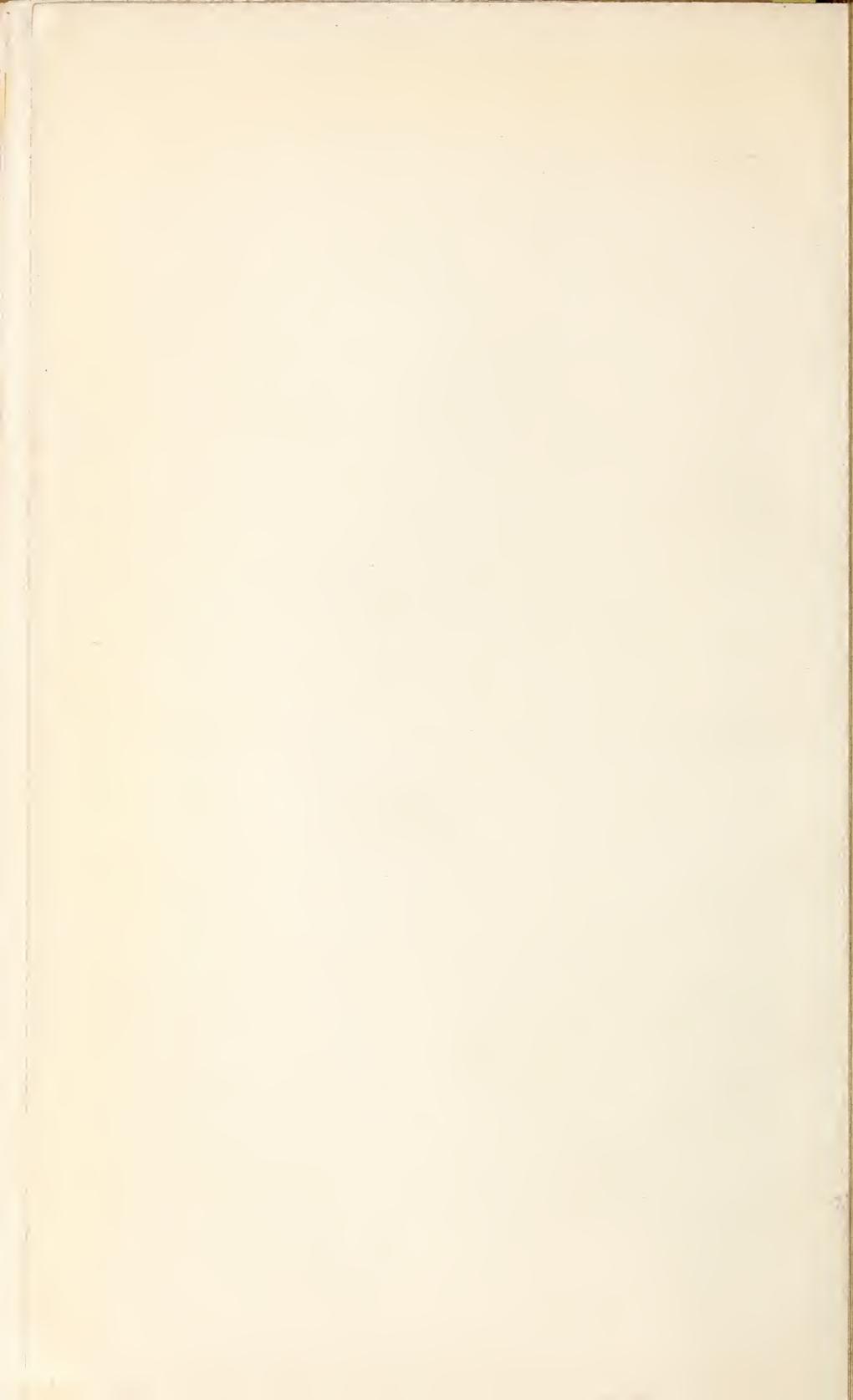




FIG. 1.—WIND EROSION OF NONPROTECTED SAND.



FIG. 2.—PROTECTING A ROAD THROUGH THE DUNES.



[Continued from page 2 of cover.]

No. 27. Letters on Agriculture in the West Indies, Spain, and the Orient. 1902.  
Price, 15 cents.

28. The Mango in Porto Rico. 1903. Price, 15 cents.

29. The Effect of Black Rot on Turnips. 1903. Price, 15 cents.

30. Budding the Pecan. 1902. Price, 10 cents.

31. Cultivated Forage Crops of the Northwestern States. 1902. Price, 10 cents.

32. A Disease of the White Ash Caused by *Polyporus Fraxinophilus*. 1903.  
Price, 10 cents.

33. North American Species of *Leptochloa*. 1903. Price, 15 cents.

34. Silkworm Food Plants. 1903. Price, 15 cents.

35. Recent Foreign Explorations. 1903. Price, 15 cents.

36. The "Bluing" and the "Red Rot" of the Western Yellow Pine, with Special Reference to the Black Hills Forest Reserve. 1903. Price, 30 cents.

37. Formation of the Spores in the Sporangia of *Rhizopus Nigricans* and of *Phycomyces Nitens*. 1903. Price, 15 cents.

38. Forest Conditions and Problems in Eastern Washington, Eastern Oregon, etc. 1903. Price, 15 cents.

39. The Propagation of the Easter Lily from Seed. 1903. Price, 10 cents.

40. Cold Storage, with Special Reference to the Pear and Peach. 1903. Price, 15 cents.

41. The Commercial Grading of Corn. 1903. Price, 10 cents.

42. Three New Plant Introductions from Japan. Price, 10 cents.

43. Japanese Bamboos. 1903. Price, 10 cents.

44. The Bitter Rot of Apples. 1903. Price, 15 cents.

45. The Physiological Rôle of Mineral Nutrients in Plants. Price, 5 cents.

46. The Propagation of Tropical Fruit Trees and Other Plants. Price, 10 cents.

47. The Description of Wheat Varieties. 1903. Price, 10 cents.

48. The Apple in Cold Storage. 1903. Price, 15 cents.

49. The Culture of the Central American Rubber Tree. 1903. Price, 25 cents.

50. Wild Rice: Its Uses and Propagation. 1903. Price, 10 cents.

51. Miscellaneous Papers: Part I. The Wilt Disease of Tobacco and its Control. 1903. Price, 5 cents. Part II. The Work of the Community Demonstration Farm at Terrell, Tex. 1904. Price, 5 cents. Part III. Fruit Trees Frozen in 1904. 1904. Price, 5 cents.

52. Wither-Tip and Other Diseases of Citrus Trees and Fruits Caused by *Colletotrichum Glaeosporioides*. 1904. Price, 5 cents.

53. The Date Palm. Price, 20 cents.

54. Persian Gulf Dates. 1903. Price, 10 cents.

55. The Dry Rot of Potatoes Due to *Fusarium Oxysporum*. 1904. Price, 10 cents.

56. Nomenclature of the Apple. [In press.]

57. Methods Used for Controlling and Reclaiming Sand Dunes. 1904. Price, 10 cents.

58. The Vitality and Germination of Seeds. 1904. Price, 10 cents.

59. Pasture, Meadow, and Forage Crops in Nebraska. 1904. Price, 10 cents.

60. A Soft Rot of the Calla Lily. [In press.]

61. The Avocado: Its Propagation, Cultivation, and Marketing. [In press.]

62. Notes on Egyptian Agriculture. [In press.]

63. Further Investigations of Rusts. [In press.]

64. A Method of Destroying or Preventing the Growth of Algae and Certain Pathogenic Bacteria in Water Supplies. 1904. Price, 5 cents.

